WEST

# Freeform Search

Database: US Patents Full-Text Database
US Pre-Grant Publication Full-Text Database
JPO Abstracts Database
EPO Abstracts Database
Derwent World Patents Index
IBM Technical Disclosure Bulletins

Term: L4 and (temperature with (static or uniform or homogeneous or main) with (magnetic adj field))

Display: 50 Documents in Display Format: - Starting with Number 1

Generate: ○ Hit List ◉ Hit Count ○ Side by Side ○ Image

Search | Clear | Help | Logout | Interrupt

Main Menu | Show S Numbers | Edit S Numbers | Preferences | Cases

## Search History

**DATE: Friday, April 12, 2002** Printable Copy Create Case

| Set Name side by side | Query | Hit Count | Set Name result set |
|---|---|---|---|
| | *DB=USPT,PGPB,JPAB,EPAB,DWPI,TDBD; PLUR=YES; OP=ADJ* | | |
| L5 | L4 and (temperature with (static or uniform or homogeneous or main) with (magnetic adj field)) | 18 | L5 |
| L4 | L3 and (((magnetic adj field) with correct$6) with temperature) | 33 | L4 |
| L3 | L2 and ((magnetic adj field) with correct$6) | 227 | L3 |
| L2 | L1 and (temperature) | 95003 | L2 |
| L1 | ((magnetic adj resonance) or MRI or NMR) | 126908 | L1 |

END OF SEARCH HISTORY

# WEST

Generate Collection | Print

**Search Results -** Record(s) 1 through 33 of 33 returned.

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☐ 1. Document ID: US 6252405 B1

L4: Entry 1 of 33 File: USPT Jun 26, 2001

US-PAT-NO: 6252405
DOCUMENT-IDENTIFIER: US 6252405 B1

TITLE: Temperature compensated NMR magnet and method of operation therefor

DATE-ISSUED: June 26, 2001

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Watkins; Ronald Dean | Niskayuna | NY | | |
| Barber; William Daniel | Ballston Lake | NY | | |
| Frischmann; Peter George | Ballston Spa | NY | | |

US-CL-CURRENT: 324/319; 324/315, 324/320

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw Desc | Image

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☐ 2. Document ID: US 6100688 A

L4: Entry 2 of 33 File: USPT Aug 8, 2000

US-PAT-NO: 6100688
DOCUMENT-IDENTIFIER: US 6100688 A

TITLE: Methods and apparatus for NQR testing

DATE-ISSUED: August 8, 2000

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Smith; John Alec Sydney | London | | | GBX |
| Shaw; Julian David | Encinitas | CA | | |

US-CL-CURRENT: 324/300; 324/307, 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw Desc | Image

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☐ 3. Document ID: US 6064206 A

L4: Entry 3 of 33 File: USPT May 16, 2000

US-PAT-NO: 6064206
DOCUMENT-IDENTIFIER: US 6064206 A

TITLE: Method of and device for determining a temperature distribution in an object by means of magnetic resonance

DATE-ISSUED: May 16, 2000

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Van Vaals; Johannes J. | Eindhoven | | | NLX |
| Smink; Jouke | Eindhoven | | | NLX |

US-CL-CURRENT: 324/312; 324/309, 324/318, 324/322, 600/412

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC
Draw Desc | Image

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4. Document ID: US 6037850 A

L4: Entry 4 of 33 File: USPT Mar 14, 2000

US-PAT-NO: 6037850
DOCUMENT-IDENTIFIER: US 6037850 A

TITLE: Superconducting magnet apparatus and method of regulating magnetization thereof

DATE-ISSUED: March 14, 2000

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Honmei; Takao | Tokyo | | | JPX |
| Takeshima; Hirotaka | Tokyo | | | JPX |
| Kawano; Hajime | Tokyo | | | JPX |
| Takuma; Yutaka | Tokyo | | | JPX |
| Kotabe; Munenori | Tokyo | | | JPX |
| Maki; Naoki | Tokai-mura | | | JPX |
| Hara; Nobuhiro | Hitachi | | | JPX |
| Kakugawa; Shigeru | Hitachi | | | JPX |
| Hino; Noriaki | Mito | | | JPX |

US-CL-CURRENT: 335/216; 324/320

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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5. Document ID: US 5814989 A

L4: Entry 5 of 33 File: USPT Sep 29, 1998

US-PAT-NO: 5814989
DOCUMENT-IDENTIFIER: US 5814989 A

TITLE: Methods and apparatus for NQR testing

DATE-ISSUED: September 29, 1998

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Smith; John Alec Syndney | London | | | GB2 |
| Shaw; Julian David | Encinitas | CA | | |
| Blanz; Martin | Culham | | | GB2 |

US-CL-CURRENT: 324/300; 324/307

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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☐ 6. Document ID: US 5596303 A

L4: Entry 6 of 33 File: USPT Jan 21, 1997

US-PAT-NO: 5596303
DOCUMENT-IDENTIFIER: US 5596303 A

TITLE: Superconductive magnet system with low and high temperature superconductors

DATE-ISSUED: January 21, 1997

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Akgun; Ali | North Andover | MA | 01845 | |
| Kerber; Michael M. | Chelmsford | MA | 01824 | |

US-CL-CURRENT: 335/216; 324/320, 335/299, 505/211, 505/879

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 7. Document ID: US 5557199 A

L4: Entry 7 of 33 File: USPT Sep 17, 1996

US-PAT-NO: 5557199
DOCUMENT-IDENTIFIER: US 5557199 A

TITLE: Magnetic resonance monitor

DATE-ISSUED: September 17, 1996

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Bowman; Joseph D. | Cincinnati | OH | | |
| Engel, III; Daniel P. | Cheviot | OH | | |

US-CL-CURRENT: 324/301; 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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## ☐ 8. Document ID: US 5545994 A

L4: Entry 8 of 33 File: USPT Aug 13, 1996

US-PAT-NO: 5545994
DOCUMENT-IDENTIFIER: US 5545994 A

TITLE: Reduction of ambient susceptibility perturbations of an NMR spectrometer

DATE-ISSUED: August 13, 1996

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Barbara; Thomas M. | Cupertino | CA | | |

US-CL-CURRENT: 324/315; 324/321

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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## ☐ 9. Document ID: US 5419142 A

L4: Entry 9 of 33 File: USPT May 30, 1995

US-PAT-NO: 5419142
DOCUMENT-IDENTIFIER: US 5419142 A

TITLE: Thermal protection for superconducting magnets

DATE-ISSUED: May 30, 1995

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Good; Jeremy A. | London W8 5JB | | | GB2 |

US-CL-CURRENT: 62/51.1; 505/890, 505/897, 62/259.2, 62/77

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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## ☐ 10. Document ID: US 5375597 A

L4: Entry 10 of 33 File: USPT Dec 27, 1994

US-PAT-NO: 5375597
DOCUMENT-IDENTIFIER: US 5375597 A

TITLE: Digital magnetic resonance shock-monitoring method

DATE-ISSUED: December 27, 1994

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Howell; Jerome C. | Chattanooga | TN | 37421 | |
| Green; Ronald P. | Carlsbad | CA | 92008 | |

US-CL-CURRENT: 600/421

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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## ☐ 11. Document ID: US 5323112 A

L4: Entry 11 of 33 File: USPT Jun 21, 1994

US-PAT-NO: 5323112
DOCUMENT-IDENTIFIER: US 5323112 A

TITLE: Reproducibly positionable NMR probe

DATE-ISSUED: June 21, 1994

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Howard; Layne E. | San Jose | CA | | |

US-CL-CURRENT: 324/318

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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## ☐ 12. Document ID: US 4876503 A

L4: Entry 12 of 33 File: USPT Oct 24, 1989

US-PAT-NO: 4876503
DOCUMENT-IDENTIFIER: US 4876503 A

TITLE: Method of measuring the intensity of a DC current and a device implementing this method

DATE-ISSUED: October 24, 1989

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Aubert; Guy | Grenoble | | | FRX |

US-CL-CURRENT: 324/117R; 324/105, 324/127

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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## ☐ 13. Document ID: US 4789833 A

L4: Entry 13 of 33 File: USPT Dec 6, 1988

US-PAT-NO: 4789833
DOCUMENT-IDENTIFIER: US 4789833 A

TITLE: Method for correcting position deviation due to static magnetic field change in NMR imaging device

DATE-ISSUED: December 6, 1988

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Nishimura; Hiroshi | Kashiwa | | | JPX |

US-CL-CURRENT: 324/320; 324/309

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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☐ 14. Document ID: US 4663592 A

L4: Entry 14 of 33 File: USPT May 5, 1987

US-PAT-NO: 4663592
DOCUMENT-IDENTIFIER: US 4663592 A

TITLE: NMR image forming apparatus

DATE-ISSUED: May 5, 1987

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Yamaguchi; Keiki | Tokyo | | | JPX |
| Inoue; Yuji | Tokyo | | | JPX |
| Iwaoka; Hideto | Tokyo | | | JPX |
| Sugiyama; Tadashi | Tokyo | | | JPX |

US-CL-CURRENT: 324/315; 324/318

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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☐ 15. Document ID: US 4509030 A

L4: Entry 15 of 33 File: USPT Apr 2, 1985

US-PAT-NO: 4509030
DOCUMENT-IDENTIFIER: US 4509030 A

TITLE: Correction coil assembly for NMR magnets

DATE-ISSUED: April 2, 1985

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Vermilyea; Mark E. | Schenectady | NY | | |

US-CL-CURRENT: 335/216; 324/320, 335/299, 505/879

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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☐ 16. Document ID: US 4321538 A

L4: Entry 16 of 33 File: USPT Mar 23, 1982

US-PAT-NO: 4321538
DOCUMENT-IDENTIFIER: US 4321538 A

TITLE: Nuclear gyromagnetic resonance apparatus

DATE-ISSUED: March 23, 1982

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Abe; Katsunobu | Ibaraki | | | JPX |
| Kimura; Satoru | Isunezumi | | | JPX |
| Kamezawa; Norimasa | Ibaraki | | | JPX |

US-CL-CURRENT: 324/318

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 17. Document ID: JP 2000342554 A

L4: Entry 17 of 33 File: JPAB Dec 12, 2000

PUB-NO: JP02000342554A
DOCUMENT-IDENTIFIER: JP 2000342554 A
TITLE: MAGNETIC RESONANCE IMAGING EQUIPMENT, AND METHOD FOR MAINTAINING HIGH UNIFORMITY OF MAGNETIC FIELD IN THE EQUIPMENT

PUBN-DATE: December 12, 2000

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| TSUDA, MUNETAKA | |

INT-CL (IPC): A61 B 5/055; G01 R 33/3875; G01 R 33/389

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 18. Document ID: JP 11195527 A

L4: Entry 18 of 33 File: JPAB Jul 21, 1999

PUB-NO: JP411195527A
DOCUMENT-IDENTIFIER: JP 11195527 A
TITLE: SUPERCONDUCTING MAGNET

PUBN-DATE: July 21, 1999

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| HAVENS, TIMOTHY J | |
| TAN, YULAN | |

INT-CL (IPC): H01 F 7/20; H01 F 6/06

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments KWIC
Draw Desc | Clip Img | Image

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## 19. Document ID: JP 08126626 A

L4: Entry 19 of 33 File: JPAB May 21, 1996

PUB-NO: JP408126626A
DOCUMENT-IDENTIFIER: JP 08126626 A
TITLE: MAGNETIC RESONANCE IMAGING APPARATUS

PUBN-DATE: May 21, 1996

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| YOSHINO, HITOSHI | |

INT-CL (IPC): A61 B 5/055; G01 R 33/385

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments KWIC
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## 20. Document ID: JP 03273181 A

L4: Entry 20 of 33 File: JPAB Dec 4, 1991

PUB-NO: JP403273181A
DOCUMENT-IDENTIFIER: JP 03273181 A
TITLE: NUCLEAR MAGNETIC RESONANCE MEASURING INSTRUMENT

PUBN-DATE: December 4, 1991

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| IKEDA, HIROSHI | |

US-CL-CURRENT: 324/309
INT-CL (IPC): G01R 33/38

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Clip Img | Image

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☐ 21. Document ID: JP 02206436 A

L4: Entry 21 of 33 File: JPAB Aug 16, 1990

PUB-NO: JP402206436A
DOCUMENT-IDENTIFIER: JP 02206436 A
TITLE: NUCLEAR MAGNETIC RESONANCE DIAGNOSTIC APPARATUS

PUBN-DATE: August 16, 1990

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| MORIYAMA, MASAO | |

INT-CL (IPC): A61B 5/055; G01R 33/38

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 22. Document ID: JP 02082943 A

L4: Entry 22 of 33 File: JPAB Mar 23, 1990

PUB-NO: JP402082943A
DOCUMENT-IDENTIFIER: JP 02082943 A
TITLE: MAGNETIC FIELD GENERATOR FOR MAGNETIC RESONANCE

PUBN-DATE: March 23, 1990

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| MIYAJIMA, TAKESHI | |
| SHUDO, TAKESHI | |
| KURODA, KUNISHIGE | |
| TAKAHASHI, TAKAO | |
| SUZUKI, SHOHEI | |

INT-CL (IPC): A61B 5/055; G01R 33/42

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Clip Img | Image

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☐ 23. Document ID: JP 01303141 A

L4: Entry 23 of 33 File: JPAB Dec 7, 1989

PUB-NO: JP401303141A
DOCUMENT-IDENTIFIER: JP 01303141 A
TITLE: PERMANENT MAGNET MAGNETIC RESONANCE IMAGING DEVICE

PUBN-DATE: December 7, 1989

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| KAMIYAMA, AKIHIDE | |

INT-CL (IPC): A61B 10/00; G01N 24/06; G01R 33/22

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Clip Img | Image

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☐ 24. Document ID: JP 63259448 A

L4: Entry 24 of 33 File: JPAB Oct 26, 1988

PUB-NO: JP363259448A
DOCUMENT-IDENTIFIER: JP 63259448 A
TITLE: MAGNET TEMPERATURE CONTROLLER FOR MAGNETIC NUCLEAR RESONATOR

PUBN-DATE: October 26, 1988

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| SHICHIJI, KUNIO | |

US-CL-CURRENT: 73/579
INT-CL (IPC): G01N 24/06; G01R 33/22

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 25. Document ID: JP 61269053 A

L4: Entry 25 of 33 File: JPAB Nov 28, 1986

PUB-NO: JP361269053A
DOCUMENT-IDENTIFIER: JP 61269053 A
TITLE: APPARATUS FOR CORRECTING UNIFORMITY OF MAGNETIC FIELD OF NMR APPARATUS

PUBN-DATE: November 28, 1986

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| SHIMAZAKI, TORU | |
| INOUE, YUJI | |
| IWAOKA, HIDETO | |

US-CL-CURRENT: 324/307
INT-CL (IPC): G01N 24/08; A61B 10/00

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 26. Document ID: JP 55061005 A

L4: Entry 26 of 33 File: JPAB May 8, 1980

PUB-NO: JP355061005A
DOCUMENT-IDENTIFIER: JP 55061005 A
TITLE: MANUFACTURE OF POLE PIECE FOR MAGNET

PUBN-DATE: May 8, 1980

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| TSUNO, KATSUSHIGE | |
| YAMAZAKI, KOICHI | |
| SUZUKI, HITOSHI | |

US-CL-CURRENT: 148/121
INT-CL (IPC): H01F 1/14; H01F 41/02; C21D 9/00; G01N 24/02

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 27. Document ID: US 5545997 A

L4: Entry 27 of 33 File: EPAB Aug 13, 1996

PUB-NO: US005545997A
DOCUMENT-IDENTIFIER: US 5545997 A
TITLE: Therapy tomograph with homogeneity device

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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☐ 28. Document ID: US 5485088 A

L4: Entry 28 of 33 File: EPAB Jan 16, 1996

PUB-NO: US005485088A
DOCUMENT-IDENTIFIER: US 5485088 A
TITLE: Therapy tomograph with homogeneity device

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Clip Img | Image

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☐ 29. Document ID: JP 2001145609 A, WO 200117428 A1

L4: Entry 29 of 33 File: DWPI May 29, 2001

DERWENT-ACC-NO: 2001-580595
DERWENT-WEEK: 200165


TITLE: Magnetic resonance imaging device

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Clip Img | Image

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30. Document ID: KR 2001051663 A, US 6252405 B1

L4: Entry 30 of 33 File: DWPI Jun 25, 2001

DERWENT-ACC-NO: 2001-578825
DERWENT-WEEK: 200172


TITLE: Constant magnetic field generator for nuclear magnetic resonance system, has correction coils that generate compensation flux based on temperature variation of magnet

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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31. Document ID: US 5545997 A, DE 19525322 C1

L4: Entry 31 of 33 File: DWPI Aug 13, 1996

DERWENT-ACC-NO: 1996-383814
DERWENT-WEEK: 199638


TITLE: Superconducting MRI appts having homogeneous magnetic field directed along Z-coordinate - has ferromagnetic homogeneity elements arranged on surface of room temp. bore on both sides of transverse access opening, and superconducting correction coils coaxial to main field coil

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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32. Document ID: GB 2285313 B, GB 2285313 A, US 5596303 A

L4: Entry 32 of 33 File: DWPI Jul 23, 1997

DERWENT-ACC-NO: 1995-227181
DERWENT-WEEK: 199732


TITLE: Superconductive magnet system comprising low and-or high temperature superconductors for MRI - has one or more coaxial superconducting coils of conventional design generating bulk of magnetic field and one or more close-in correction rings or coils of high temperature superconducting material

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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33. Document ID: WO 8504020 A, DE 3570756 G, EP 175789 A, EP 175789 B, JP 61501341 W, US 4587492 A

L4: Entry 33 of 33 File: DWPI Sep 12, 1985

DERWENT-ACC-NO: 1985-236479
DERWENT-WEEK: 198538


TITLE: Thermal barrier for variable temperature NMR - eliminates variable influence on gradient coil temperature and consequent resistance in NMR imaging systems

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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| Term | Documents |
| --- | --- |
| MAGNETIC.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 1063275 |
| MAGNETICS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 9565 |
| FIELD.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 2193304 |
| FIELDS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 284107 |
| CORRECT$6 | 0 |
| CORRECT.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 558711 |
| CORRECTA.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 121 |
| CORRECTAB.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 1 |
| CORRECTABALE.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 2 |
| CORRECTABILI.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 1 |
| (L3 AND (((MAGNETIC ADJ FIELD) WITH CORRECT$6) WITH TEMPERATURE)).USPT,PGPB,JPAB,EPAB,DWPI,TDBD. | 33 |

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**Display Format:** - Change Format

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**Search Results -** Record(s) 1 through 18 of 18 returned.

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☐ 1. Document ID: US 6252405 B1

L5: Entry 1 of 18 File: USPT Jun 26, 2001

US-PAT-NO: 6252405
DOCUMENT-IDENTIFIER: US 6252405 B1

TITLE: Temperature compensated NMR magnet and method of operation therefor

DATE-ISSUED: June 26, 2001

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Watkins; Ronald Dean | Niskayuna | NY | | |
| Barber; William Daniel | Ballston Lake | NY | | |
| Frischmann; Peter George | Ballston Spa | NY | | |

US-CL-CURRENT: 324/319; 324/315, 324/320

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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☐ 2. Document ID: US 6064206 A

L5: Entry 2 of 18 File: USPT May 16, 2000

US-PAT-NO: 6064206
DOCUMENT-IDENTIFIER: US 6064206 A

TITLE: Method of and device for determining a temperature distribution in an object by means of magnetic resonance

DATE-ISSUED: May 16, 2000

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Van Vaals; Johannes J. | Eindhoven | | | NLX |
| Smink; Jouke | Eindhoven | | | NLX |

US-CL-CURRENT: 324/312; 324/309, 324/318, 324/322, 600/412

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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☐ 3. Document ID: US 6037850 A

L5: Entry 3 of 18 File: USPT Mar 14, 2000

US-PAT-NO: 6037850
DOCUMENT-IDENTIFIER: US 6037850 A

TITLE: Superconducting magnet apparatus and method of regulating magnetization thereof

DATE-ISSUED: March 14, 2000

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Honmei; Takao | Tokyo | | | JPX |
| Takeshima; Hirotaka | Tokyo | | | JPX |
| Kawano; Hajime | Tokyo | | | JPX |
| Takuma; Yutaka | Tokyo | | | JPX |
| Kotabe; Munenori | Tokyo | | | JPX |
| Maki; Naoki | Tokai-mura | | | JPX |
| Hara; Nobuhiro | Hitachi | | | JPX |
| Kakugawa; Shigeru | Hitachi | | | JPX |
| Hino; Noriaki | Mito | | | JPX |

US-CL-CURRENT: 335/216; 324/320

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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## 4. Document ID: US 5375597 A

L5: Entry 4 of 18 File: USPT Dec 27, 1994

US-PAT-NO: 5375597
DOCUMENT-IDENTIFIER: US 5375597 A

TITLE: Digital magnetic resonance shock-monitoring method

DATE-ISSUED: December 27, 1994

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Howell; Jerome C. | Chattanooga | TN | 37421 | |
| Green; Ronald P. | Carlsbad | CA | 92008 | |

US-CL-CURRENT: 600/421

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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## 5. Document ID: US 5323112 A

L5: Entry 5 of 18 File: USPT Jun 21, 1994

US-PAT-NO: 5323112
DOCUMENT-IDENTIFIER: US 5323112 A

TITLE: Reproducibly positionable NMR probe

DATE-ISSUED: June 21, 1994

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Howard; Layne E. | San Jose | CA | | |

US-CL-CURRENT: 324/318

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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☐ 6. Document ID: US 4789833 A

L5: Entry 6 of 18 File: USPT Dec 6, 1988

US-PAT-NO: 4789833
DOCUMENT-IDENTIFIER: US 4789833 A

TITLE: Method for correcting position deviation due to static magnetic field change in NMR imaging device

DATE-ISSUED: December 6, 1988

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Nishimura; Hiroshi | Kashiwa | | | JPX |

US-CL-CURRENT: 324/320; 324/309

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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☐ 7. Document ID: US 4663592 A

L5: Entry 7 of 18 File: USPT May 5, 1987

US-PAT-NO: 4663592
DOCUMENT-IDENTIFIER: US 4663592 A

TITLE: NMR image forming apparatus

DATE-ISSUED: May 5, 1987

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Yamaguchi; Keiki | Tokyo | | | JPX |
| Inoue; Yuji | Tokyo | | | JPX |
| Iwaoka; Hideto | Tokyo | | | JPX |
| Sugiyama; Tadashi | Tokyo | | | JPX |

US-CL-CURRENT: 324/315; 324/318

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

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## ☐ 8. Document ID: JP 11195527 A

L5: Entry 8 of 18 File: JPAB Jul 21, 1999

PUB-NO: JP411195527A
DOCUMENT-IDENTIFIER: JP 11195527 A
TITLE: SUPERCONDUCTING MAGNET

PUBN-DATE: July 21, 1999

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| HAVENS, TIMOTHY J | |
| TAN, YULAN | |

INT-CL (IPC): H01 F 7/20; H01 F 6/06

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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## ☐ 9. Document ID: JP 02206436 A

L5: Entry 9 of 18 File: JPAB Aug 16, 1990

PUB-NO: JP402206436A
DOCUMENT-IDENTIFIER: JP 02206436 A
TITLE: NUCLEAR MAGNETIC RESONANCE DIAGNOSTIC APPARATUS

PUBN-DATE: August 16, 1990

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| MORIYAMA, MASAO | |

INT-CL (IPC): A61B 5/055; G01R 33/38

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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## ☐ 10. Document ID: JP 02082943 A

L5: Entry 10 of 18 File: JPAB Mar 23, 1990

PUB-NO: JP402082943A
DOCUMENT-IDENTIFIER: JP 02082943 A
TITLE: MAGNETIC FIELD GENERATOR FOR MAGNETIC RESONANCE

PUBN-DATE: March 23, 1990

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| MIYAJIMA, TAKESHI | |
| SHUDO, TAKESHI | |
| KURODA, KUNISHIGE | |
| TAKAHASHI, TAKAO | |
| SUZUKI, SHOHEI | |

INT-CL (IPC): A61B 5/055; G01R 33/42

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 11. Document ID: JP 61269053 A

L5: Entry 11 of 18 File: JPAB Nov 28, 1986

PUB-NO: JP361269053A
DOCUMENT-IDENTIFIER: JP 61269053 A
TITLE: APPARATUS FOR CORRECTING UNIFORMITY OF MAGNETIC FIELD OF NMR APPARATUS

PUBN-DATE: November 28, 1986

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| SHIMAZAKI, TORU | |
| INOUE, YUJI | |
| IWAOKA, HIDETO | |

US-CL-CURRENT: 324/307
INT-CL (IPC): G01N 24/08; A61B 10/00

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 12. Document ID: JP 55061005 A

L5: Entry 12 of 18 File: JPAB May 8, 1980

PUB-NO: JP355061005A
DOCUMENT-IDENTIFIER: JP 55061005 A
TITLE: MANUFACTURE OF POLE PIECE FOR MAGNET

PUBN-DATE: May 8, 1980

INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| TSUNO, KATSUSHIGE | |
| YAMAZAKI, KOICHI | |
| SUZUKI, HITOSHI | |

US-CL-CURRENT: 148/121

INT-CL (IPC): H01F 1/14; H01F 41/02; C21D 9/00; G01N 24/02

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 13. Document ID: US 5545997 A

L5: Entry 13 of 18 File: EPAB Aug 13, 1996

PUB-NO: US005545997A
DOCUMENT-IDENTIFIER: US 5545997 A
TITLE: Therapy tomograph with homogeneity device

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 14. Document ID: US 5485088 A

L5: Entry 14 of 18 File: EPAB Jan 16, 1996

PUB-NO: US005485088A
DOCUMENT-IDENTIFIER: US 5485088 A
TITLE: Therapy tomograph with homogeneity device

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 15. Document ID: JP 2001145609 A, WO 200117428 A1

L5: Entry 15 of 18 File: DWPI May 29, 2001

DERWENT-ACC-NO: 2001-580595
DERWENT-WEEK: 200165


TITLE: Magnetic resonance imaging device

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 16. Document ID: US 5545997 A, DE 19525322 C1

L5: Entry 16 of 18 File: DWPI Aug 13, 1996

DERWENT-ACC-NO: 1996-383814
DERWENT-WEEK: 199638


TITLE: Superconducting MRI appts having homogeneous magnetic field directed along Z-coordinate - has ferromagnetic homogeneity elements arranged on surface of room temp. bore on both sides of transverse access opening, and superconducting correction coils coaxial to main field coil

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 17. Document ID: GB 2285313 B, GB 2285313 A, US 5596303 A

L5: Entry 17 of 18 File: DWPI Jul 23, 1997

DERWENT-ACC-NO: 1995-227181
DERWENT-WEEK: 199732


TITLE: Superconductive magnet system comprising low and-or high temperature superconductors for MRI - has one or more coaxial superconducting coils of conventional design generating bulk of magnetic field and one or more close-in correction rings or coils of high temperature superconducting material

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 18. Document ID: WO 8504020 A, DE 3570756 G, EP 175789 A, EP 175789 B, JP 61501341 W, US 4587492 A

L5: Entry 18 of 18 File: DWPI Sep 12, 1985

DERWENT-ACC-NO: 1985-236479
DERWENT-WEEK: 198538


TITLE: Thermal barrier for variable temperature NMR - eliminates variable influence on gradient coil temperature and consequent resistance in NMR imaging systems

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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| Term | Documents |
|---|---|
| TEMPERATURE.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 2158264 |
| TEMP.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 761693 |
| TEMPS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 79152 |
| TEMPERATURES.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 606537 |
| STATIC.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 272820 |
| STATICS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 853 |
| UNIFORM.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 867312 |
| UNIFORMS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 1239 |
| HOMOGENEOUS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB. | 195275 |
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DOCUMENT-IDENTIFIER: US 6252405 B1
TITLE: Temperature compensated NMR magnet and method of operation therefor

Abstract Paragraph Left (1):
An MRI system includes a magnet which produces the main polarizing magnetic field. Variations in strength of this field are corrected by a temperature compensation system that calculates a compensating flux needed to maintain the field at constant strength. The compensating flux is calculated from changes in sensed magnet temperature and a magnet temperature coefficient. One or more correction coils are wound around the magnet and driven with the current necessary to produce the compensating flux.

Brief Summary Paragraph Right (1):
This invention relates to nuclear magnetic resonance (NMR) imaging systems and methods and, more particularly, to systems and methods which compensate NMR image quality for temperature effects on the NMR system magnet.

Brief Summary Paragraph Right (2):
In the past, the NMR phenomenon has been utilized by structural chemists to study, in vitro, the molecular structure of organic molecules. Typically, NMR spectrometers utilized for this purpose were designed to accommodate relatively small samples of the substance to be studied. More recently, however, NMR has been developed into an imaging modality utilized to obtain images of anatomical features of live human subjects, for example. Such images depicting parameters associated with nuclear spins (typically spins of hydrogen protons associated with water in tissue) may be of medical diagnostic value in determining the state of health of tissue in the region examined. NMR techniques have also been extended to in vivo spectroscopy of such elements as phosphorus and carbon, for example, providing researchers with tools, for the first time, to study chemical processes in a living organism. The use of NMR to produce images and spectroscopic studies of the human body has necessitated use of specifically designed system components, such as the magnet, gradient and RF coils.

Brief Summary Paragraph Right (3):
By way of background, the nuclear magnetic resonance phenomenon occurs in atomic nuclei having an odd number of protons or neutrons. Due to the spin of the protons and neutrons, each such nucleus exhibits a magnetic moment such that, when a sample composed of such nuclei is placed in a static, homogeneous magnetic field B.sub.0, a majority of nuclear magnetic moments align with the field to produce a net macroscopic magnetization M in the direction of the field. Under the influence of the magnetic field B.sub.0, the aligned magnetic moments precess about the axis of the field at a frequency dependent on the strength of the applied magnetic field and on the characteristics of the nuclei. The angular precession frequency .omega., also referred to as the Larmor frequency, is given by the Larmor equation .omega.=.gamma.B in which .gamma. is the gyromagnetic ratio (which is constant for each NMR isotope) and wherein B is the magnetic field (B.sub.0 plus other fields) acting upon the nuclear spins. It is thus apparent that the resonant frequency is dependent on the strength of the magnetic field in which the sample is positioned.

Brief Summary Paragraph Right (4):
The orientation of magnetization M, normally directed along the magnetic field B.sub.0, may be perturbed by the application of magnetic fields oscillating at or near the Larmor frequency. Typically, such magnetic fields designated B.sub.1, are generated orthogonally to the direction of the B.sub.0 field by RF pulses supplied through a coil connected to an RF transmitting apparatus. Under the influence of RF

excitation, magnetization M rotates about the direction of the B.sub.1, field. In NMR studies, it is typically desired to apply RF pulses of sufficient magnitude and duration to rotate magnetization M into a plane perpendicular to the direction of the B.sub.0 field. This plane is commonly referred to as the transverse plane. Upon cessation of the RF excitation, the nuclear moments rotated into the transverse plane precess around the direction of the static field. The vector sum of the spins forms a precessing bulk magnetization which can be sensed by an RF coil. The signals sensed by the RF coil, termed NMR signals, are characteristic of the magnetic field and of the particular chemical environment in which the nuclei are situated. In magnetic resonance imaging (MRI) systems, which are systems that employ NMR imaging, the NMR signals are observed in the presence of magnetic-field gradients which are utilized to encode spatial information into the signals. This information is later used to reconstruct images of the object studied in a manner well-known to those skilled in the art.

Brief Summary Paragraph Right (5):
A common NMR imaging problem results from the temperature dependent nature concerning operation of NMR magnetic sources, such as a permanent magnet used to produce the B.sub.0 field (the "B.sub.0 magnet"). That is, temperature changes in the B.sub.0 magnet alter the strength of the otherwise static B.sub.0 field. Temperature changes are the ordinary consequence of temperature gradients in a testing room, such as may result from localized positioning of warm lights or air conditioning/heating vents. Temperature gradients may cause different parts of the magnet to have different temperatures. For example, warm lighting located in the ceiling may cause an upper part of a magnet to be warmer than its corresponding lower portion. Alternatively, the entire magnet may have the same temperature, but one that changes over time, such as when a room heats up or cools down over the course of a day.

Brief Summary Paragraph Right (6):
Regardless of whether the B.sub.0 magnet is subjected to localized or generalized temperature variation, it is desirable for NMR imaging to produce a homogeneous B.sub.0 field of precise strength, typically for extended periods of time. However, normal temperature changes in the B.sub.0 magnet (as discussed above) lead to undesirable variations in B.sub.0 field strength, which changes the Larmor frequency, resulting in image degradation.

Brief Summary Paragraph Right (7):
What is needed is a system and method to compensate for temperature changes in the B.sub.0 magnet, thereby improving NMR image quality.

Brief Summary Paragraph Right (8):
The invention permits maintaining consistent B.sub.0 field strength, thereby improving NMR image quality. This is accomplished by determining temperature of the magnet providing the B.sub.0 field. This temperature and a known coefficient are used to determine how much the B.sub.0 field will vary (without flux compensation) from the desired B.sub.0 field strength due to magnet temperature deviating from an ideal operating temperature. The known coefficient governs the relationship between magnet temperature and the impact of magnet temperature on the resulting B.sub.0 field. A driver provides current through one or more correction coils around one or more portions of the magnet to furnish an amount and polarity of compensating flux appropriate to maintain B.sub.0 field consistency, thereby compensating for temperature variation of the magnet and the associated impact on B.sub.0 field strength.

Drawing Description Paragraph Right (1):
FIG. 1 is a block diagram of an MRI system employing the invention;

Drawing Description Paragraph Right (2):
FIG. 2 is a perspective view of a polarizing magnet for the MRI system of FIG. 1;

Detailed Description Paragraph Right (1):
FIG. 1 illustrates the major components of a magnetic resonance imaging (MRI) system which incorporates the invention. System operation is controlled from an operator console 100 which includes a keyboard and control panel 102 and a display 104. Console 100 communicates through a link 116 with a separate computer system 107 that enables an operator to control the production and display of images on screen 104. The computer system includes a number of modules which communicate with each other through a backplane 109. These modules include an image processor 106, a CPU 108 and

a memory 113, known in the art as a frame buffer for storing image data arrays. Computer system 107 is linked to a disk storage 111 and tape drive 112 for storage of image data and programs, and communicates with a separate system control 122 through a high speed serial link 115.

Detailed Description Paragraph Right (4):
A transceiver module 150 in system control 122 produces pulses that are amplified by an RF amplifier 151 and provided to RF coil 152 by a transmit/receive switch 154. The resulting signals radiated by the excited nuclei in the patient may be sensed by the same RF coil 152 and provided through transmit/receive switch 154 to a preamplifier 153. The amplified NMR signals are demodulated, filtered, and digitized in the receiver section of transceiver 150. Transmit/receive switch 154 is controlled by a signal from pulse generator module 121 to electrically couple RF amplifier 151 to coil 152 for the transmit mode and to couple preamplifier 153 to coil 152 for the receive mode. Transmit/receive switch 154 also enables a separate RF coil, for example, a head coil or surface coil, (not shown) to be used in either the transmit or receive mode.

Detailed Description Paragraph Right (5):
The NMR signals picked up by RF coil 152 are digitized by transceiver module 150 and transferred to a memory module 160 in system control 122. When the scan is completed and an entire array of data has been acquired in memory module 160, an array processor 161 operates to Fourier transform the data into an array of image data. These image data are conveyed through serial link 115 to computer system 107 where they are stored in disk memory 111. In response to commands received from operator console 100, these image data may be archived on tape drive 112, or may be further processed by image processor 106 and conveyed to operator console 100 for presentation on display 104.

Detailed Description Paragraph Right (7):
A temperature compensation system 180 determines the requisite amount and polarity of flux to add to the static B.sub.0 field produced by polarizing magnet 140 to compensate for temperature-induced variation in the B.sub.0 field and to maintain B.sub.0 field homogeneity. In making this determination, system 180 senses polarizing magnet temperature to determine its deviation from ideal operating temperature. Alternatively, Larmor frequency may be sensed to establish deviation from ideal Larmor frequency, as this frequency difference is related to deviation from ideal operating temperature for polarizing magnet 140. From the amount of deviation from ideal temperature or ideal Larmor frequency, and utilizing a stored coefficient governing the impact of these deviations on B.sub.0 field strength, system 180 computes compensation flux and provides suitable current through one or more correction coils (shown in FIG. 2) which wrap around polarizing magnet 140 to produce the desired compensation flux and/or are located on the gradient assembly 139 or RF assembly 152.

Detailed Description Paragraph Right (8):
FIG. 2 is a simplified representation of polarizing magnet 140, used to produce the main polarizing magnetic field or B.sub.0 field 168, and may also be referred to as "B.sub.0 magnet 140." Magnet 140 includes two opposing permanent magnets, namely upper magnet 162 and lower magnet 164, separated by an imaging volume 170 (or gap), thru which B.sub.0 field 168 passes. B.sub.0 magnet 140 may comprise any conventional magnetic source for B.sub.0 field 168, such as an iron-core-resistive electromagnet or a superconducting magnet, though permanent magnets are typically used. Permanent magnets are particularly susceptible to temperature-driven variations, as manifested in the B.sub.0 field which they produce. Thus, permanent magnets 162 and 164 typically have conventionally determined coefficients which govern the relationship between magnet temperature and B.sub.0 field 168 which they produce. This change in B.sub.0 field 168 as a function of magnet temperature is expressed as a temperature coefficient which is measured or is provided by the magnet supplier.

Detailed Description Paragraph Right (14):
Operation of temperature compensation system 180 is represented by FIG. 4. To simplify the discussion of system operation, reference is made simply to B.sub.0 magnet 140, understanding that all of the different forms that it may take (including the pair of opposing magnets 162 and 164 from FIG. 2) may be used in the system.

Detailed Description Paragraph Right (15):

As a first step 182, temperature of B.sub.0 magnet 140 is conventionally obtained. For example, temperature at given locations may be obtained by use of infrared radiation sensors, or by temperature sensors 141, such as thermocouples or thermistors, placed on, or embedded in, one or more appropriate locations of B.sub.0 magnet 140. Direct temperature readings taken at one or more locations of B.sub.0 magnet 140 may also be used in conventional manner to extrapolate temperatures for various positions in B.sub.0 magnet 140.

Detailed Description Paragraph Right (16):
Alternatively, magnet temperature may be ascertained indirectly in temperature compensation system 180 by determining the difference in Larmor frequency under two conditions. Specifically, the Larmor frequency obtained under ideal operating conditions is compared with the Larmor frequency obtained under present operating conditions. The computed difference in Larmor frequency is attributable in large part to B.sub.0 magnet 140 being at other than ideal operating temperature. This is understood by recalling that Larmor frequency is proportionately related to the magnitude of B.sub.0 field 168, the strength of which is related to the temperature of B.sub.0 magnet 140.

Detailed Description Paragraph Right (17):
Now, the temperature of B.sub.0 magnet 140 being known, this information is used at step 184 to determine the amount of B.sub.0 field compensation required to maintain a uniform B.sub.0 field 168. The relationship between the temperature of B.sub.0 magnet 140 and the B.sub.0 field which it produces is given by a temperature-to-field-strength conversion coefficient (more simply referred to hereafter as the "TTFS coefficient"). This temperature coefficient can be measured, but it typically is provided by the magnet manufacturer and can be expressed in units of parts per million per degree Celsius (PPM/.degree. C.). For example, B.sub.0 magnet 140 may be a Neodymium Iron Boron (NdFeB) magnet. Such magnets are generally sensitive to temperature changes, and have a negative TTFS coefficient of approximately 0.13%/.degree. C. or 1300 PPM/.degree. C. Here, PPM may refer to a ratio of B.sub.0 field strength (e.g., micro-Tesla/Tesla, or micro-gauss/gauss) or a ratio of Larmor frequency (e.g., hertz/mega-hertz).

Detailed Description Paragraph Right (18):
Thus, the amount of B.sub.0 field compensation required for B.sub.0 field homogeneity is determined using the change from ideal magnet temperature (or ideal Larmor frequency) and the TTFS coefficient for B.sub.0 magnet 140. As part of this determination, if the temperature of B.sub.0 magnet 140 increases, the strength of B.sub.0 field 168 becomes reduced, necessitating addition of like polarity compensating flux to maintain the B.sub.0 field constant. Alternatively, a temperature decrease for B.sub.0 magnet 140 increases B.sub.0 field magnitude, requiring employment of an opposing polarity compensating flux to maintain the B.sub.0 field constant.

Detailed Description Paragraph Right (21):
Whether a single driver is used in a series or parallel coil configuration, or even if multiple independent drivers are used, each configuration may be used to provide different quantities and/or polarities of compensation flux per correction coil 166. As suggested, it may be advantageous to have different flux compensation distributions (e.g., in a room having locally high temperatures in proximity to ceiling lighting).

CLAIMS:

1. Apparatus for producing a substantially constant polarizing magnetic field in an NMR system, which comprises:

a) a magnet for producing a static polarizing magnetic field that changes in strength as a function of magnet temperature;

b) means responsive to temperature of the magnet during an imaging operation for determining a compensating flux based upon said temperature; and

c) correction coils for producing the determined compensating flux such that the sum of said compensating flux and the polarizing magnetic field flux remains substantially constant as variations occur in magnet temperature.

8. The apparatus of claim 1 wherein the means responsive to temperature of the

magnet comprises temperature sensors.

9. The apparatus of claim 8 wherein the temperature sensors are selected from the group consisting of thermocouples, thermistors, and infrared radiation sensors.

10. A method of compensating for temperature-induced variations in a static polarizing field produced by a magnet of an MRI system, comprising the steps of:

a) sensing magnet temperature during an imaging operation;

b) determining a compensating magnetic flux from the sensed magnet temperature and a magnet temperature coefficient; and

c) supplying the compensating magnetic flux through a correction coil so as to combine the compensating flux with the polarizing field.

13. Apparatus for producing a substantially constant polarizing magnetic field in an NMR system, which comprises:

a) a magnet for producing a static polarizing magnetic field that changes in strength as a function of magnet temperature;

b) means for measuring Larmor frequency and determining a compensating flux based upon any difference between larmor frequency during actual operating conditions and larmor frequency under ideal operating conditions; and

c) a correction coil for producing the calculated compensating flux such that the sum of said compensating flux and the polarizing magnetic field flux remains substantially constant as variations occur in magnet temperature.

L5: Entry 2 of 18 File: USPT May 16, 2000

DOCUMENT-IDENTIFIER: US 6064206 A
TITLE: Method of and device for determining a temperature distribution in an object by means of magnetic resonance

Abstract Paragraph Left (1):
The invention relates to a method of determining, utilizing magnetic resonance, a temperature distribution of a part of an object which is arranged in a substantially uniform steady magnetic field, the determination of the temperature distribution involving the determination of a reference image of the object, for example a part of the human body, and a phase image of the human body. Subsequently, the temperature distribution is determined from phase differences between the values of pixels of the phase image and the values of corresponding pixels of a predetermined reference phase image. In order to counteract errors in the temperature distribution which are caused by motion of the object, navigator pulse sequences are generated so as to measure navigator signals prior to the measurement of MR signals wherefrom the reference image and the phase image are reconstructed. Subsequently, a correction for correction of the temperature distribution is derived from the navigator signals.

Brief Summary Paragraph Right (2):
The invention relates to a method of determining a temperature distribution of a part of an object, arranged in a substantially uniform, steady magnetic field, by means of magnetic resonance, which method includes the following steps: excitation of spins in the part and measurement of MR signals, containing location-dependent information of the excited spins, by means of MR imaging pulse sequences, determination of a phase image of the part from the measured MR signals, determination of a temperature distribution of the part from phase differences between the values of pixels of the phase image and the values of corresponding pixels of a predetermined reference phase image. The invention also relates to a device for carrying out such a method.

Brief Summary Paragraph Right (5):
A method of this kind is known from international patent application WO 25 94/23308. The known method is used, for example to determine a temperature distribution in a part of the human body. Such a part is, for example, a slice of the body which contains a tumor to be destroyed, said tumor being heated to a temperature beyond a limit temperature. In order to minimize the damage to other tissue of the body, it is necessary to have an accurate temperature distribution of the part available before and during the heating. This temperature distribution is formed by execution of the known method. For example, an ultrasonic source can be used to heat the tumor, the sound waves to be generated are then focused onto the part to be heated. In order to determine the temperature distribution of the part at a number of successive instants during the heating of the tumor, the reference phase image of the part to be heated is determined prior to the heating of the tumor, after which the MR signals of the part to be heated are measured by means of the MR imaging pulse sequences at the given instants during the heating. Subsequently, the phase image is reconstructed from the measured MR signals. The temperature distribution of the part to be heated is derived from the phase differences between the values of corresponding pixels of the reference phase image and the phase image. Subsequently, information derived from the temperature distribution obtained can be used to control the heating process, for example by determining the position of the heated location in the part from the temperature distribution.

Brief Summary Paragraph Right (6):
It is a drawback of the known method that the temperature distribution contains

errors which are caused by movement of the part of the body whose temperature distribution has been determined.

Brief Summary Paragraph Right (7):
It is an object of the invention to reduce the errors in the temperature distribution which are caused by movement of the part of the body in the steady magnetic field. To this end, the method according to the invention is characterized in that it also includes the following steps: excitation of spins in a first reference part of the object, a motion of which is related to a motion of the part, and measurement of a navigator signal by means of a first navigator pulse sequence, and determination of a shift in a measuring direction of the first navigator pulse sequence from the measured navigator signal and a predetermined reference so as to determine a correction for correcting the temperature distribution. The invention is based on the idea that the movement of the object may cause different errors which contribute to the phase differences between corresponding pixels of the reference phase image and the phase image, the temperature distribution being determined from said phase differences. Analysis of the navigator signals, for which a modulus as well as a phase of the navigator signals are available, can produce information concerning the motion of the part to be heated or concerning other causes of errors in the temperature distribution, for example inhomogeneities of the steady magnetic field which are due to the presence of other parts of the object, such as a shoulder of the human body which is present in the steady magnetic field. Subsequently, the information obtained is used to apply a correction to the temperature distrubution, for example a correction prior to or during the measurement of the MR signals or retrospectively, in which case the correction is applied to the temperature distribution at a later stage.

Brief Summary Paragraph Right (8):
Navigator signals are known per se from U.S. Pat. No. 4,937,526. However, according to the method disclosed in the cited patent a motion correction is determined by means of navigator signals which are not measured independently of the MR signals for reconstructing an MR image. The navigator signals are also known from the international patent application WO-A-96116340; however, the method disclosed in the latter patent application is used to determine a correction for MR images which is derived by means of navigator signals measured in a reference part whose motion is related to the part whose temperature distribution is determined. The correction known from the latter patent application, however, does not relate to the correction of phases of temperature images.

Brief Summary Paragraph Right (9):
A special version of the method according to the invention is characterized in that the method includes a step in which the correction is applied to the MR signals used to reconstruct the phase image in order to correct these signals for a shift of the slice. Thus, for example a correction can be made for frequency and phase errors which are dependent on the position of the part within the body and are caused by a temporally varying deviation in the steady magnetic field which is caused by a change of susceptibility in the object, for example a tissue transition such as the liver-lung transition in the human body. This correction can be made prior to or during the measurement of the MR signals.

Brief Summary Paragraph Right (11):
pulse sequence succeeding the first navigator pulse sequence being corrected for the shift of the slice. As a result of this step, the spins of the part whose temperature is to be determined are excited in the shifted position.

Brief Summary Paragraph Right (14):
A further version of the method according to the invention is characterized in that the method includes a step in which the correction also includes a phase correction of a pixel of the temperature distribution of the slice in a first position, said phase correction being determined by a phase difference between a first measuring point of the reference, which corresponds to the first position, and a second measuring point of the navigator signal which corresponds to a second position of the part, said second position having been shifted in the measuring direction relative to the first position. Thus, a correction is made for a phase error which is caused by a temporally fixed deviation in the steady magnetic field which is caused by another, non-moving part of the body, for example a shoulder, or is caused by a permanent inhomogeneity within the steady magnetic field, as opposed to the previously mentioned phase errors which are dependent on the position of the part within the body and are caused by a temporally varying deviation in the steady

magnetic field.

Brief Summary Paragraph Right (15):
A further version of the method according to the invention is characterized in that a cylindrical part is chosen as the first reference part. As a result, 2 DHF pulses can be used to generate navigator signals. The 2 DHF pulses are known from the article "A k-space analysis of small tip angle excitation", by J. Pauli et al, published in Journal of Magnetic Resonance 1989, No. 81, pp. 43-56.

Brief Summary Paragraph Right (18):
The invention also relates to an MR device for measuring a temperature distribution of a part of an object, characterized in that the control means are also arranged to measure, using a navigator pulse sequence, a navigator signal in a reference part of an object to be arranged in the MR device, a motion of said reference part being related to the part of the object whose temperature distribution is determined, and that the processing unit is also arranged to determine a shift in a measuring direction of the navigator pulse sequence from the measured navigator signal and a predetermined reference, and to determine a correction from the shift so as to correct the temperature distribution.

Drawing Description Paragraph Right (6):
FIG. 4 shows a pencil-shaped reference part and the slice for which a temperature distribution is to be determined, and

Detailed Description Paragraph Right (1):
FIG. 1 shows a magnetic resonance device. The magnetic resonance device includes a first magnet system 2, a second magnet system 3, a power supply unit 4, an RF transmitter and modulator 6, an RF transmitter coil 5, a transmitter-receiver circuit 9, a signal amplifier and demodulation unit 10, a processing unit 12, an image processing unit 13, a monitor 14 and a control unit 11. The first magnet system 2 serves to generate a steady magnetic field. The various gradient coils of the second magnet system 3 serve to generate additional magnetic fields having a gradient in the X, Y, Z directions, respectively. The Z direction of the co-ordinate system shown in FIG. 1 corresponds by convention to the direction of the steady magnetic field in the magnet system 2. The measuring co-ordinate system x, y, z to be used may be chosen independently of the X, Y, Z system shown in FIG. 1. In the context of the present application gradients are to be understood to mean temporary magnetic fields which are superposed on a steady magnetic field and cause a gradient in the steady magnetic field in three respective orthogonal directions. Generally speaking, a gradient in the first direction is referred to as a read-out gradient, a gradient in the second direction as a phase encoding gradient, and a gradient in the third direction as a selection gradient.

Detailed Description Paragraph Right (2):
The gradient coils 3 are fed by the power supply unit 4. The RF transmitter coil 5 serves to generate RF magnetic fields and is connected to the RF transmitter and modulator 6. A receiver coil is used to receive the magnetic resonance signal generated by the RF field in the object 7 to be examined, for example a human or animal body. This coil may be the same coil as the RF transmitter coil 5. The magnet system 2 encloses an examination space which is large enough to accommodate a part of the body 7 to be examined. The RF transmitter coil 5 is arranged around or on a part of the body 7 within the examination space. The RF transmitter coil 5 is connected to the signal amplifier and demodulation unit 10 via the transmitter-receiver circuit 9. The control unit 11 controls the RF transmitter and modulator 6 and the power supply unit 4 so as to generate special pulse sequences which contain RF pulses and gradients. The MR signals received by means of the receiver coil 5 are applied, via the transmitter-receiver circuit 9, to the signal amplifier and demodulation unit 10. The phase and amplitude provided by the signal amplifier and demodulation unit 10 are applied to the processing unit 12. The processing unit 12 processes the applied phases and amplitudes, by way of a transformation, to an image of the part of the body. Via the image processing unit 13, the image can be visualized on the monitor 14. The MR device also includes an ultrasonic source 15 for heating the part of the body to be treated, for example a tumor in the liver.

Detailed Description Paragraph Right (3):
The invention will be described in detail hereinafter, by way of example, on the basis of an MR method which utilizes an MR imaging pulse sequence, for example a gradient echo pulse sequence, for measuring MR signals of a part of the body

 

containing a zone to be heated, for example a slice in the liver which contains the tumor, the zone to be heated in the slice being adjusted in such a manner that it coincides with a part of the tumor. The gradient echo pulse sequence is known inter alia from "Practical NMR imaging", by M. A. Foster and J. M. S. Hutchison, 1987, IRL Press.

Detailed Description Paragraph Right (5):
In order to enable a temperature distribution of the slice of the body to be followed in time, a reference image is formed prior to inducing a temperature variation in the zone to be heated, after which a phase image is determined at predetermined instants. In order to determine the reference image, MR signals 140 of the slice are measured by means of said gradient echo pulse sequences 20. Subsequently, the reference phase image is determined from the measured MR signals by means of a two-dimensional Fourier transformation. Subsequently, a temperature variation is induced in the slice.

Detailed Description Paragraph Right (6):
In order to determine the phase image at one of the predetermined instants during or after the heating, for example 256 MR signals 140, originating from the slice to be imaged, are measured by means of 256 successive gradient echo pulse sequences 20. The phase image is determined from these MR signals by means of two-dimensional Fourier transformation. The temperature distribution of the slice imaged is derived from the phase differences between the values of corresponding pixels of the predetermined reference phase image and the phase image. Subsequently, the temperature distribution obtained can be visualized on the monitor 14 and used, for example to control the heating process. This is done, for example, to adapt the dimensions of the zone to be heated in the liver. This method is known from the cited WO 94/23308.

Detailed Description Paragraph Right (7):
The temperature variation can be realized, for example by heating the zone to be heated by generating ultrasonic waves by means of an ultrasonic source 15 and by concentrating these waves on the part of the liver to be heated. Another possibility is to apply light to the zone to be heated, the light being generated by a light source (not shown) and being conducted to the zone to be heated via an optical conductor to be introduced into the body (not shown). It is also to be noted that a temperature variation can also be realized by cooling the part of the body by means of cryo-ablation. Cryo-ablation is known from the article "Hepatic Cryosurgery with Intraoperative U.S. Guidance", published by F. T. Lee et al. in Radiology No. 202, 1997, pp. 624-632.

Detailed Description Paragraph Right (8):
In order to counteract deviations in the temperature distribution due to a motion of the body in, for example the z direction, the method according to the invention includes the measurement of navigator signals from a reference part by generating a navigator pulse sequence prior to the gradient echo pulse sequences 20, the reference part being chosen in such manner that the motion of the reference part is related to the part to be heated. FIG. 3 shows an example of a navigator pulse sequence.

Detailed Description Paragraph Right (9):
FIG. 3 shows a navigator pulse sequence 30. The navigator pulse sequence 30 includes a two-dimensional (2D) RF pulse or a three-dimensional (3D) RF pulse for the excitation of spins in a cylindrical reference part, for example a first pencil-shaped reference part, and a read-out gradient. The 2D-RF pulse includes an excitation RF pulse 200 which has a flip angle .alpha..sub.nav. A practical value used for .alpha..sub.nav is, for example 10.degree.. The selective excitation of the first pencil-shaped reference part 40 is achieved by means of a first gradient 220 and a second gradient 230 which are oriented perpendicularly to a direction of motion. In FIG. 3 the first and the second gradient are oriented in the x direction and the y direction, respectively. A 3D-RF pulse can be used instead of a 2D-RF pulse. The 2D-RF pulse and the 3D-RF pulse are known from the previously cited article "A k-space analysis of small tip angle excitation", by J. Pauli et al., published in Journal of Magnetic Resonance 1989, No. 81, pp. 43-56. Using a third gradient 210, the spins are dephased and rephased so that an in-phase state is reached and a navigator signal 240 is measured a period of time .tau..sub.1 after the excitation RF pulse 200. Frequency modulation of the navigator signal 240 is achieved by sustaining the third gradient. The third gradient 210 of the navigator pulse sequence 30 is oriented in a direction of motion of the first reference part

41 and will be referred to hereinafter as the navigator gradient. The direction of the navigator gradient is referred to as the measuring direction. In this example the measuring direction coincides with the z direction. Furthermore, the pencil-shaped reference part of the body 7 is chosen in such a manner that it contains a part of a lung and a part of the diaphragm of the body 7. A first version of the method will be described in detail hereinafter with reference to FIG. 4.

Detailed Description Paragraph Right (10):
FIG. 4 shows the first pencil-shaped reference part 40 and a slice whose temperature distribution is to be determined. An example of such a slice is a slice 41 of the liver in which a tumor 42 is located. In FIG. 4 the first reference part 40 is oriented in the z direction and the slice 41 extends substantially perpendicularly to the z direction. The reference part 40 may be, for example pencil-shaped. In order to acquire motion information from the slice, for example a first navigator signal of the first reference part is measured by generating a first navigator pulse sequence prior to a gradient echo pulse sequence which is generated so as to measure the MR signal which is used for the reconstruction of the reference image, and a second navigator signal of the first reference part by generating a second navigator pulse sequence prior to a gradient echo pulse sequence which is generated so as to measure an MR signal which is used for the reconstruction of the phase image. This combination of navigator pulse sequences and gradient echo pulse sequences will be described in detail with reference to FIG. 5.

Detailed Description Paragraph Right (13):
applied to the temperature distribution when the shift in the measuring direction is known.

Detailed Description Paragraph Right (14):
In order to apply the correction to the temperature distribution, according to the first version of the invention the processing unit 12 derives a first motion correction signal 16 from the shift .delta.s.sub.z determined, a value of the first motion correction signal 16 then corresponding to a frequency correction ##EQU1## in which .gamma. represents the giro magnetic ratio, .delta.s.sub.z represents the shift in the measuring direction, and G.sub.z represents the selection gradient of the gradient echo pulse sequence 20. The first motion correction signal 16 is applied to a modulation input of the RF modulator 6, so that the RF modulator adapts a frequency content of the second RF pulse 100' of a gradient echo pulse sequence succeeding the second navigator pulse sequence, so that the zone to be imaged coincides with the moving slice 41 in the body to be imaged, and the zone to be imaged in the steady magnetic field follows a motion of the slice 41 to be imaged in the body. Using this adjustment of the first motion correction signal 16, subsequently the 256 MR signals for the reconstruction of the phase image are measured. Subsequently, using a two-dimensional Fourier transformation, the processing unit 12 reconstructs the phase image of the part 41 and the temperature distribution from the difference between the predetermined reference image and the phase image. When the shift .delta.s.sub.z exceeds a predetermined threshold value, it is also possible to abstain from generating gradient echo pulse sequences and to generate only the navigator pulse sequences until the shift .delta.s.sub.z drops below the predetermined threshold value.

Detailed Description Paragraph Right (18):
A fourth version of the method according to the invention is used to determine a phase correction for the temperature distribution which provides a correction for a motion in the z direction and for a temporally constant deviation in the steady magnetic field which is caused by a magnetic field component. This constant deviation may be due to a part of the body which does not move relative to the steady magnetic field, for example a shoulder of the body. Another cause of said deviation is, for example an inhomogeneity of the steady magnetic field. In order to determine the latter phase correction, the processing unit 12 determines two phase sequences .PHI..sub.nav1 (z), .PHI..sub.nav2 (z), using a one-dimensional Fourier transformation, from the measured first and second navigator signals z.sub.nav1, z.sub.nav2 240, 240'. These phase sequences contain the phase of the navigator signal as a function of the distance in the z direction along the first pencil-shaped reference part 40. The processing unit 12 subsequently performs a phase correction in conformity with the formule .PHI.'(x.sub.i,y.sub.j)=.PHI.(x.sub.i,y.sub.j)+(.PHI..sub.nav1 (z.sub.1)-.PHI..sub.nav2 (z.sub.2)), where .PHI.(x.sub.i,y.sub.j) represents the phase of a pixel (x.sub.i,y.sub.j) of the temperature distribution, .PHI.'(x.sub.i,y.sub.j) represents the phase of a pixel (x.sub.i,y.sub.j) of the

corrected temperature distribution, .PHI..sub.nav1 represents the phase sequence of the second navigator signal z.sub.nav1 240, and .PHI..sub.nav2 represents the phase sequence of the second navigator signal z.sub.nav2 240', for all points (x.sub.i,y.sub.j) of the temperature distribution of a slice in a position z.sub.1 for a shift by .delta.s.sub.z to a second position z.sub.2 in the measuring direction. As a result of the correction applied to all pixels of the temperature distribution, the phase of a pixel (x.sub.i,y.sub.j) of the temperature distribution of the slice 40 is corrected by the correction determined by a phase difference between a first measuring point of the first navigator signal z.sub.nav1 240, corresponding to the first position z.sub.1 of a pixel of the slice, and a second measuring point of the navigator signal z.sub.nav2 240', corresponding to a second position z.sub.2 of the voxel, said second position z.sub.2 having been shifted in the first measuring direction relative to the first position. In this example the correction can also be achieved by determining a fourth motion correction signal from the phase correction and adding the fourth motion correction signal to the third motion correction signal 18.

Detailed Description Paragraph Right (19):
In order to correct a phase variation due to a motion in an arbitrary direction as caused by temporally fixed deviations, use is made of a fifth version of the invention in which the processing unit 12 determines the phase sequences .PHI.x.sub.nav1 (x),.PHI.x.sub.nav2 (x),.PHI.y.sub.nav1 (y),.PHI.y.sub.nav2 (y),.PHI.z.sub.nav1 (z),.PHI.z.sub.nav2 (z) from the first to the sixth navigator signal x.sub.nav1, x.sub.nav2, y.sub.nav1, y.sub.nav2, z.sub.nav1, z.sub.nav2, where .PHI.x.sub.nav1 (x), .PHI.x.sub.nav1 (x) represent phases of the measured third and fourth navigator signals x.sub.nav1, x.sub.nav2 in a position x along the second pencil-shaped reference part 43, .PHI.y.sub.nav1 (y), .PHI.y.sub.nav1 (y) represent phases of the measured fifth and sixth navigator signals y.sub.nav1, y.sub.nav2 in a position y along the third pencil-shaped reference part 44, and .PHI.z.sub.nav1 (z), .PHI.z.sub.nav1 (z) represent phases of the measured first and second navigator signals z.sub.nav1, z.sub.nav2 in a position z along the first pencil-shaped reference part 40. The phase correction for a pixel (x.sub.i,y.sub.j) of the temperature distribution of a slice in a first slice position (x.sub.1,y.sub.1,z.sub.1,) whereto the reference image corresponds for a shift to a second slice position (x.sub.1, y.sub.1,z.sub.1) whereto the phase image corresponds is then determined by .PHI.'(i,j)=.PHI.(i,j)+(.PHI.x.sub.nav1 (x.sub.1)-.PHI.x.sub.nav2 (x.sub.2)+(.PHI.y.sub.nav1 (y.sub.1)-.PHI.y.sub.nav2 (y.sub.2))+(.PHI.z.sub.nav1 (z.sub.1)-.PHI.z.sub.nav2 (z.sub.2)), where .PHI.'(i,j) represents the corrected phase of a pixel (x.sub.i,y.sub.j) of the temperature distribution, .PHI.(i,j) represents the phase of a pixel (x.sub.i,y.sub.j) of the temperature distribution, .PHI.x.sub.nav1 (x.sub.1) represents the phase of the third navigator signal x.sub.nav1 in the position x.sub.1, .PHI.x.sub.nav2 (x.sub.2) represents the phase of the fourth navigator signal x.sub.nav2 in the position x.sub.2, .PHI.y.sub.nav1 (y.sub.1) represents the phase of the fifth navigator signal y.sub.nav1 in the position y.sub.1, .PHI.y.sub.nav2 (y.sub.2) represents the phase of the sixth navigator signal y.sub.nav2 in the position y.sub.2, .PHI.z.sub.nav1 (z.sub.1) represents the phase of the first navigator signal z.sub.nav1 in the position z.sub.1, and .PHI.z.sub.nav2 (z.sub.2) represents the phase of the second navigator signal z.sub.nav2 in the position z.sub.2.

Detailed Description Paragraph Right (20):
In order to achieve a further reduction of the phase errors in the temperature distribution, shimming of the steady magnetic field can be performed at the area of the slice whose temperature distribution is to be determined.

CLAIMS:

1. A method of determining a temperature distribution of a part of an object, arranged in a substantially uniform steady magnetic field, by means of magnetic resonance, which method comprises the following steps:

excitation of spins in the part and measurement of MR signals, containing location-dependent information of the excited spins, by means of MR imaging pulse sequences,

determination of a phase image of the part from the measured MR signals,

determination of a temperature distribution of the part from phase differences between the values of pixels of the phase image and the values of corresponding

pixels of a predetermined reference phase image, wherein the method also includes the following steps:

excitation of spins in a first reference part of the object, a motion of which is related to a motion of the part, and measurement of a navigator signal by means of a first navigator pulse sequence, and

determination of a shift in a measuring direction of the first navigator pulse sequence from the measured navigator signal and a predetermined reference so as to determine a correction for correcting the temperature distribution.

3. The method of claim 2, wherein the correction also includes a phase correction of a pixel of the temperature distribution of the part in a first position, said phase correction being determined by a phase difference between a first measuring point of the reference, which corresponds to the first position, and a second measuring point of the navigator signal which corresponds to a second position of the part, said second position having been shifted in the measuring direction relative to the first position.

10. A method as claimed in claim 1, wherein the correction also includes a phase correction of a pixel of the temperature distribution of the part in a first position, said phase correction being determined by a phase difference between a first measuring point of the reference, which corresponds to the first position, and a second measuring point of the navigator signal which corresponds to a second position of the part, said second position having been shifted in the measuring direction relative to the first position.

14. An MR device for measuring a temperature distribution of a part of an object comprising:

means for sustaining a substantially steady magnetic field,

means for generating magnetic field gradients,

means for generating RF fields,

means for receiving and processing the generated MR signals,

control means for generating control signals for the means for generating magnetic field gradients and the means for generating RF fields,

a processing unit for reconstructing a phase image from the processed MR signals and a temperature distribution from phase differences between values of corresponding pixels of the phase image and a predetermined reference phase image, and

means for displaying a temperature distribution, wherein the control means are also arranged to measure, using a navigator pulse sequence, a navigator signal in a reference part of an object arranged in the MR device, a motion of said reference part being related to the part of the object whose temperature distribution is determined, and wherein the processing unit is also arranged to determine a shift in a measuring direction of the navigator pulse sequence from the measured navigator signal and a predetermined reference, and to determine a correction from the shift so as to correct the temperature distribution.